Engineering the electromagnetic vacuum for controlling light with light in a photonic bandgap micro-chip

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We consider electromagnetic vacuum density of states engineering in a 3D photonic bandgap material as a mechanism for providing low threshold, high speed nonlinear optical response. This provides an alternative to conventional all-optical switching schemes based on micro-cavity resonators with a Kerr-nonlinear response exhibiting the fundamental trade-off between switching time and switching threshold intensity. Our vacuum engineering involves a trimodal waveguide architecture in a 3D photonic bandgap material with a fork-like local electromagnetic density of states (LDOS). Two wave-guide modes increase the electromagnetic LDOS (near their cutoff frequencies) by a factor of 100 or more relative to the background LDOS of a third air-waveguide mode with nearly linear dispersion. Atoms in this "engineered vacuum" can be coherently pumped to a population inverted state, which can then be used to coherently amplify fast optical pulses propagating through the third waveguide mode. This nonlinear switching of atomic population occurs for pump power level on the scale of a micro-Watt. The resulting coherent "control of light with light" occurs without recourse to micro-cavity resonances (involving long cavity build-up and decay times for the optical field). Thus, enables rapid modulation (switching) of light.

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[2] S. John and R. Wang, *Photonic Nanostructures*, **2**, 137 (2004).